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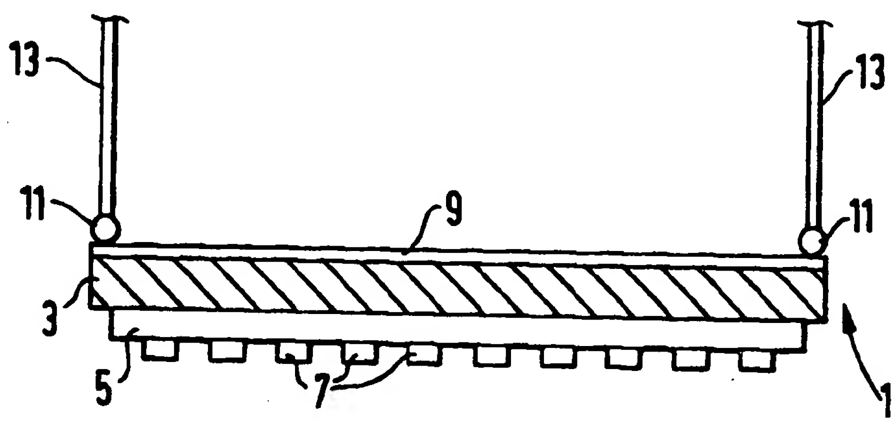
(54) Title: ELECRIC HEATERS



(57) Abstract

A thick film heater comprises an electrically insulating layer provided on a substrate, and a resistive heating track applied to the insulating layer. The substrate is composed of a steel with a carbon content of less than 0.01 %.

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Electric Heaters

The present invention relates to electric heaters of the type comprising an electrically insulating layer provided on a substrate and having applied thereto an electrically resistive heating track.

Electric heaters of the above type are known, for example, as components of liquid heating vessels and are commonly referred to as "thick film heaters". When used in a liquid heating vessel such a heater may form the base or a part of the base of the vessel, usually with the surface of the substrate provided with the insulating layer provided on the dry side of the base and not contacting the liquid. Examples of heaters of this type are disclosed in our applications WO94/18807, GB-A-2296847 and WO96/18331.

Conventionally, heaters of this type for use in liquid heating vessels have comprised a stainless steel substrate. Stainless steel has been used because the liquid contacting side of the heater must not be corroded by the liquid in the vessel, generally water. However, the 400 series stainless steels which are generally used as the substrate for such heaters are subject to pitting corrosion, particularly when used with chlorinated water. Thus, such steels are not, in fact, truly stainless in this application. Unsightly oxides form on the surface of the steel during processing and the stainless steel must be thoroughly cleaned and polished to become aesthetically acceptable and to restore its stainless properties. For this reason, surface coatings have often been applied to the liquid facing surface of the stainless steel substrate to prevent contact with the liquid in the vessel and to present a cosmetic finish. Thus, the stainless properties of stainless steel are not used when a surface coating is applied.

The applicant has realised that it is not necessary

for stainless steel to be used as a substrate in such heaters and has identified the necessary requirements for the substrate of such a heater.

In general, the insulating layer will be of glass, glass ceramic or ceramic (hereinafter collectively referred to as "ceramic"), and the substrate should therefore be of sufficient mechanical stability to support the ceramic layer and prevent the ceramic layer from cracking. If the substrate forms the base or part of the base of a liquid heating vessel, the substrate should have sufficient mechanical stability to support the liquid in the vessel and withstand the knocks of every day use and cleaning.

The type and thickness of ceramic used for the insulating layer is determined by electrical insulation requirements. According to International Specifications, the ceramic layer must be able to withstand a 1500V potential difference between the heating track and the substrate without breaking down. Furthermore, as the ceramic layer is a thermal insulator it is desirable for the ceramic layer to be as thin as possible, while still meeting electrical insulation requirements, to maximise heat conduction from the heater track to the substrate. Of course, the ceramic must also be able to withstand the temperatures encountered during normal and abnormal operating conditions of the heater, without adverse effects on the desired electrical properties. These requirements determine the ceramic material to be used, which in turn determines at least some of the properties of the substrate.

Ceramic materials are available that meet the electrical and thermal properties described above, and such ceramics generally have high melting points, for example greater than 800°C. Thus, the substrate must be able to withstand such temperatures when the ceramic layer is fired on the substrate. For example, aluminium

which is a good thermal conductor is unsuitable for use with such ceramics as it has a melting point of 660°C. In addition, the substrate material should not be sufficiently reactive that its surface will oxidise considerably at these temperatures.

The ceramic layer is generally applied to the substrate by screen printing, spraying or electrostatic spraying (as described in GB 2306873), etc. and is then fired on the substrate to produce the required insulating layer. The insulating layer adheres to the surface of the substrate. The lateral mechanical strength of the ceramic layer is low when the ceramic is held in tension, but is improved when the ceramic is held in compression. Thus, it is desirable for the substrate to have a greater coefficient of thermal expansion than the ceramic material such that on cooling of the heater after firing, the substrate contracts more than the ceramic layer, thereby putting the ceramic layer in compression. The difference in coefficients of thermal expansion between the ceramic and the substrate should not be too great, as in that case the bond between the ceramic layer and the substrate may fail, or the heater may bow (in the same way as a bimetal), or the stresses in the ceramic material may reduce the desired electrical properties of the ceramic layer. It has been found empirically by the applicant that the coefficient of thermal expansion of the substrate should be 1.25 to 1.75 times that of the ceramic.

The above requirements are met by the existing stainless steels which are used as substrates in known heaters. However, it has been realised by the applicant that stainless steel has a low thermal conductivity and forms a high percentage of the total thermal resistance between the element track and the liquid (typically greater than 40 to 60%).

This is significant in that the running temperature of the heating track is directly related to the thermal

resistance between the heating track and the liquid, which thermal resistance includes the substrate and the ceramic insulating layer. In effect, the more thermal resistance there is between the heating track and the liquid, the higher the temperature at which the heating track must run to maintain a desired temperature at the liquid contacting surface of the heater for a given power output.

From a first aspect, the invention provides an electric heater comprising an electrically insulating layer provided on a substrate, the insulating layer having a resistive heating track applied thereto, wherein the insulator is a ceramic (as defined herein) material having a melting point greater than 800°C and the substrate material has a coefficient of thermal expansion less than 15×10^{-6} $°C^{-1}$ and a thermal conductivity greater than 50 Wm^{-1} $°C^{-1}$.

Thus the heater according to the invention has the advantage that the substrate and ceramic layer meet all the requirements described above as to their relative coefficients of thermal expansion, but the substrate has a higher thermal conductivity than has previously been available using known stainless steel substrates. The increase in thermal conductivity means that the temperature of the heating track in operation is lower than has previously been known for the same power output. This lower temperature has the advantage of prolonging the life of the heater in use and allowing the use of temperature sensitive actuators for controlling the heater that operate at a lower temperature.

Moreover, the greater thermal conductivity of the substrate will allow greater lateral heat flow within the substrate to give a more even heat distribution and prevent localised hot spots occurring on the heater.

From a further aspect, the invention provides an electric heater comprising an electrically insulating

layer provided on a substrate, the insulating layer having an electrically resistive heating track applied thereto, wherein the insulating layer is a thin layer of ceramic (as defined herein) material capable of withstanding a potential difference of 1500V, the substrate has a coefficient of thermal expansion between 1.25 and 1.75 times that of the ceramic material and the substrate has a thermal conductivity greater than 50 Wm^{-1} $°C^{-1}$.

Preferably, the substrate is metallic. In the preferred embodiment the substrate comprises mild steel, for example with a carbon content of less than 0.01%, more preferably less than 0.005%. The low carbon content of the steel prevents the build-up of carbides on the surface of the steel when the steel is treated at high temperatures such as 800°C. The mild steel may be surface treated, for example with aluminium, to limit the oxidation of the steel at the high temperatures involved in firing the ceramic layer.

Thus, from another aspect the invention provides an electric heater comprising an electrically insulating ceramic (as herein defined) layer provided on a substrate, the insulating layer having a resistive heating track applied thereto, wherein the substrate is composed of a mild steel with a carbon content of less than 0.01%.

Clearly, with a mild steel substrate, or any other substrate subject to corrosion, which will contact the liquid, for example water, in a liquid heating vessel, measures should be taken to prevent corrosion of the substrate. For example, the substrate may be coated with a suitable coating, such as PTFE or DuPont "Silverstone"®. Alternatively, the substrate may be electroplated with a suitable corrosion resistant metal. However, in a preferred embodiment the liquid facing side of the substrate is provided with a layer of ceramic (as herein defined). Preferably, this layer of

ceramic is of the same material as the insulating layer, for reasons of simplicity of manufacture and thermal expansion, and may be applied by a similar process and preferably at the same time in a single coating process. The liquid-facing ceramic layer may be significantly thinner than the insulating layer if it does not serve any electrical insulation purpose, for example in an earthed appliance. It may therefore be of only sufficient thickness to provide a consistent, pin-hole free layer, such that the overall thermal conductivity of the substrate including this layer is not significantly reduced. Typically this layer may be about 15 microns thick. This ceramic layer should extend across all regions of the substrate that are likely to contact the liquid in use.

The provision of ceramic layers on both sides of the substrate has the advantage that the stresses introduced by the differential in the coefficients of thermal expansion of the materials act to cancel each other out and thereby maintain the substrate substantially flat. The thin layers of ceramic also act mechanically to strengthen the substrate.

Thus, from yet another aspect, the invention provides an electric heater comprising an electrically insulating ceramic layer (as defined herein) provided on a metallic substrate, the insulating layer having an electrically resistive heating track applied thereto, wherein the substrate is substantially flat and is provided with a further ceramic (as herein defined) layer on its surface opposite to the surface provided with the first ceramic layer.

Preferably the metallic substrate is less than 1mm thick, more preferably not greater than 0.7mm.

Our application WO 96/18331 discloses a thick film heater with a ceramic layer on both sides of the substrate. However, that substrate is not substantially flat as it requires strengthening peripheral flanges to

maintain its mechanical stability.

Most preferably, the insulating layer extends not only over the respective faces of the substrate but also over the edges of the plate, so that the whole plate is completely covered with insulation. This is preferable in that it allows the heater to receive a Class II rating, ie the heater is double insulated, meaning that it does not have to be earthed. Preferably, the coating thickness is the same or similar on both sides of the plate. Typically the thickness is between 70-150 μm , most preferably around 100 μm.

The invention also extends to an electric heater comprising a steel substrate with an insulating layer of the same material and the same or similar thickness provided on both surfaces thereof and substantially around the whole edge thereof.

Heaters in accordance with the invention can be produced in any conventional manner, for example screen printing the various layers of insulator. However higher production rates may be achieved by applying at least the insulating layers in other ways. For example, an insulating layer can be applied to a great degree of accuracy on one side of a plate by using a curtain coating system. In such a system the plate passes under a curtain of insulator in a carrier liquid and is coated to a high degree of accuracy by controlling the speed of the plate.

A further process which is also extremely suitable is electrophoretic deposition. In this process, the plate is dipped into a bath containing a slurry of insulator in a suitable carrier. An electric potential is applied between the bath and the plate so as to deposit a layer of insulator on both sides, and on the edge of the plate. The process can be controlled to give a desired thickness of coating, but generally the thickness is substantially similar on both sides.

In a preferred embodiment, the plates may be passed

through the bath in a continuous process by being suitably joined together. Most preferably, the plates may be formed from a strip of material which has been punched or the like to produce the appropriate plate shape, joined together at at least one edge. That edge of the strip then serves as a carrier for the plates not only through the insulator dipping process, but also through subsequent manufacturing steps, such as the deposition and firing of the heating tracks, and so on. The strip of partly formed heaters can be rolled up for storage purposes during manufacture and unrolled as needed at the next process step. When the heater plates are removed from the carrier, there will be an exposed edge of bare metal. In double insulated heaters, this bare material should be covered with more insulator and then fired so as to achieve a complete coating of the product. Conveniently this firing may be conducted at the same time as another firing step, for example, the firing of the overglaze traditionally applied to the heater.

From a further aspect, the invention provides a method of manufacturing a thick film heater comprising the steps of forming a series of heater plates in a strip of material such that the said heater plates are joined to the strip at their respective edges, passing the joined plates through a series of process steps including forming one or more insulation layers on said plates, separating said plates from said strip, and covering the exposed metal edge of the plate at the separation location with an insulating material.

The plates are preferably joined to a strip of material to one side of the plates by a series of bridges which can be broken to separate the plates. Preferably the strip is provided with indexing means to allow accurate location of the plates during processing, eg during deposition of heating tracks.

A pre-coated metal substrate which has proven

particularly suitable for producing heaters in accordance with the invention is Fujimetax porcelain enamelled steel plate, produced by Fujikura Limited of Japan. This product comprises a decarburised steel substrate with an alkali-free crystallised porcelain enamel insulating layer, usually on both sides thereof. It comes in a range of substrate thicknesses, typically 0.4-1.6 mm and a range of insulator thicknesses, typically 100-200μm. Such a substrate has not previously been considered as being suitable for power heating applications, and from a further aspect, the invention provides a heater comprising a decarburised steel substrate having a porcelain enamel insulating layer on at least one side thereof, and a thick film heating track deposited on an or said insulating layer. The invention also extends to a water heating apparatus comprising such a heater.

Alternatively to the provision of a surface coating or ceramic layer on its water facing side, the substrate may be attached, for example by brazing, to the underside of the base of a metallic, for example stainless steel, liquid heating vessel. In this way, it is not necessary for the stainless steel vessel to undergo the higher temperature heating processes such as are required for the firing of the ceramic layer(s) and the stainless steel vessel is thus less susceptible to oxidation during processing and thus easier to polish subsequently. Indeed the vessel could be made, for example from 300 series steel, as is commonly the case now. Furthermore, the high thermal conductivity of the substrate advantageously distributes the heat generated by the heating track evenly over the base of the vessel. Advantageously, any mounting bosses or the like that are required to project from the heating track side of the heater may be captured between the stainless steel vessel and substrate during brazing and project through the substrate. Alternatively such fixing may be folded

up out of the substrate prior to brazing.

The heater need not be attached to an entire metal vessel. For example the heater may be attached, for example laminated, to a plate or the like which may form the base of a plastics or metal water heating vessel. The plate may be of stainless steel and may be attached to the plastics vessel in the manner described in WO 96/18331.

Some embodiments of the invention will now be described by way of example only and with reference to the accompanying figures in which:

Figure 1 is a schematic sectional representation of an electric heater according to the present invention;

Figure 2 is a schematic sectional representation of a heater according to the invention attached to a metal liquid heating vessel;

Figure 3 is a schematic sectional representation of a heater according to the invention attached to a metal plate for use in a base of a liquid heating vessel;

Figure 4 is a schematic section through a further heater in accordance with the invention; and

Figure 5 shows, schematically, an intermediate stage in the manufacture of a heater in accordance with the invention.

As shown in Figure 1, an electric heater 1 comprises a 0.7mm thick substrate 3 of VE grade mild steel. The substrate 3 is provided with a 100 micron ceramic insulating layer 5 of a suitable ceramic in known manner. For example, the mild steel substrate may be blasted with grit to clean the surfaces to which the ceramic is applied before application of the ceramic. A resistive heating track 7 is provided on the ceramic layer 5 also in known manner. A further protective layer 9 of ceramic is provided on the other side of the substrate 3 to the insulating layer 5 and is 30 microns thick. The protective layer 9 extends towards the edge of the substrate 3 a sufficient distance that it ends

further out than the seal 11 which is provided below the plastics wall 13 of the water heating vessel to which the heater 1 is attached by clamping means (not shown).

The VE grade mild steel has a thermal conductivity of 65 Wm^{-1} $°C^{-1}$ compared to 22 Wm^{-1} $°C^{-1}$ for 400 series stainless steel and 16 Wm^{-1} $°C^{-1}$ for 300 series stainless steel. The coefficient of linear expansion of the mild steel is $12x10^{-6}$ $°C^{-1}$ compared to $8x10^{-6}$ $°C^{-1}$ for the ceramic. 400 and 300 series stainless steels have respective coefficients of thermal expansion of $10x10^{-6}$ $°C^{-1}$ and $16x10^{-6}$ $°C^{-1}$.

Thus, the heater 1 of figure provides greater heat transfer from the heater track 7 to the water even with the insulating effect of the protective layer 9, while maintaining mechanical stability and the necessary matching of thermal expansion coefficients.

Testing has shown that the track temperature for the heater 1 shown in Figure 1 operating at a power density of 0.61 W mm^{-2} is approximately 5°C below that of an equivalent stainless steel heater operating at the same power density.

Figure 2 shows a heater 1 similar to that shown in Figure 1. However, in this case the heater does not include a protective layer 9 on the substrate 3. Instead the substrate 3 is brazed directly onto a stainless steel plate 15 such as is described in WO 96/18331. In this way, the plate 15 may be fixed onto a plastic walled vessel by means of the peripheral deformable grooves 16 in known manner, while maintaining the increased heat output described in relation to Figure 1.

Figure 3 shows a heater 1 similar to that shown in Figure 2, but in this case the heater is brazed onto the base of stainless steel heating vessel 17.

Figure 4 shows a yet further embodiment of the invention. In this embodiment, the heater comprises a decarburised steel substrate 3 which is completely

coated on both surfaces and around its edge with a fired insulating layer 5 of crystallised porcelain enamel. The layer 5 is of generally constant thickness. Such a substrate is available commercially as Fujikura Limited's "Fujimetax" steel board. The heating track 7 is deposited on the insulating layer 5 in a conventional manner. This heater may be mounted in the base of a liquid heating vessel in any suitable manner.

Figure 5 shows schematically an intermediate step in the manufacture of a heater in accordance with the invention. This figure shows a series of plates 21 which have been punched out of a strip of steel material 23. One edge 25 of the strip 23 is left intact and is joined to the individual plates 21 by bridges 27 of material. Indexing holes 29 are formed in the edge 25 to assist in the accurate movement of plates through a series of process steps. These may include, sequentially: the deposition of one or more insulating layers, eg by an electrophoretic process; the firing of these layers; and the deposition of a heating track on the insulation.

After the plates 21 have passed through the requisite number of stages, they are separated from the edge 25 at the inner end 31 of the bridges. If necessary, for example where a double insulated heater is required, the raw edge of the plate left at the point of separation may be covered with an insulator and fired, possibly at the same time as the firing of the protective overglaze which is normally provided over the tracks. This overglaze preferably is applied while the plates are joined together, but not fired until separation of the plates from the strip 25.

It will be appreciated that the above described invention allows heaters for liquid heating apparatus to be economically produced. Such heaters will generally have a power rating of at least 500W, and more preferably 1kW or more, when connected to a mains power

supply eg a 100, 110 or 220/240 V supply. They are thus to be distinguished from thick film electronic components which are not designed for heating purposes.

Claims

1. An electric heater comprising an electrically insulating layer provided on a substrate, the insulating layer having a resistive heating track applied thereto, wherein the insulator is a ceramic (as defined herein) material having a melting point greater than 800°C and the substrate material has a coefficient of thermal expansion less than 15×10^{-6} $°C^{-1}$ and a thermal conductivity greater than 50 Wm^{-1} $°C^{-1}$.

2. An electric heater comprising an electrically insulating layer provided on a substrate, the insulating layer having an resistive heating track applied thereto, wherein the insulating layer is a thin layer of ceramic (as defined herein) material capable of withstanding a potential difference of 1500V, the substrate has a coefficient of thermal expansion between 1.25 and 1.75 times that of the ceramic material and the substrate has a thermal conductivity greater than 50 Wm^{-1} $°C^{-1}$.

3. A heater as claimed in claim 1 or 2 wherein said the substrate is of a steel having a carbon content of less than 0.01%.

4. An electric heater comprising an electrically insulating ceramic (as herein defined) layer provided on a substrate, the insulating layer having a resistive heating track applied thereto, wherein the substrate is composed of a steel with a carbon content of less than 0.01%.

5. A heater as claimed in claim 3 or 4 wherein the carbon content is less than 0.005%.

6. A heater as claimed in any preceding claim wherein the substrate is provided on both sides with a layer of

ceramic.

7. A heater as claimed in claim 6 wherein the insulating layer extends over the edges of the substrate.

8. A heater as claimed in any preceding claim wherein the insulating layer is 70-150 μm thick.

9. An electric heater comprising a decarburised steel substrate with an enamel insulating layer provided thereon with a thick film heating track provided on the insulating layer.

10. A electric heater comprising a steel substrate with an insulating layer of the same material and the same or similar thickness provided on both surfaces thereof and substantially around the whole edge thereof.

11. A liquid heating apparatus comprising a heater as claimed in any preceding claim.

12. Apparatus as claimed in claim 11 wherein the heater closes an opening in the base of the apparatus.

13. Apparatus as claimed in claim 11 wherein the heater is attached to the underside of the base of a metallic heating vessel.

14. A method of manufacturing a thick film heater comprising the steps of forming a series of heater plates in a strip of material such that the said heater plates are joined to the strip at their respective edges, passing the joined plates through a series of process steps including forming one or more insulation layers on said plates and separating said plates from said strip.

15. A method as claimed in claim 14 further comprising subsequently covering the exposed metal edge of the plate at the separation location with an insulating material.

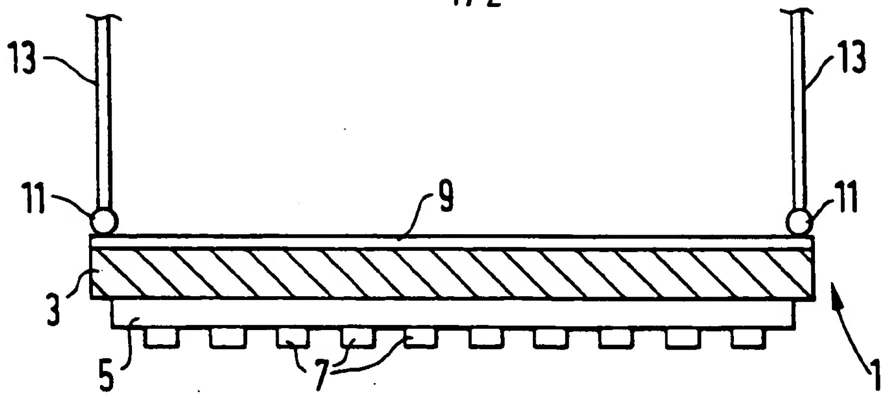

FIG.1

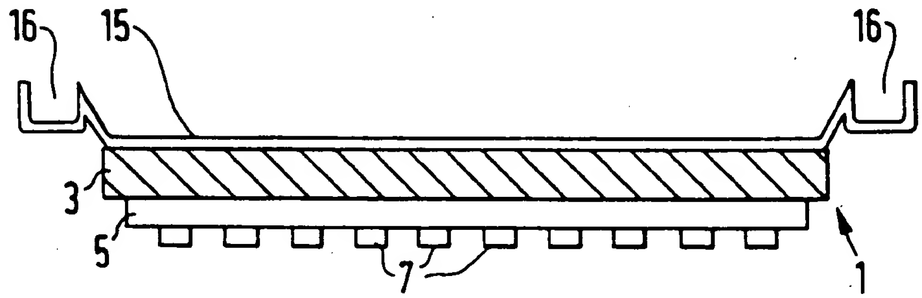

FIG.2

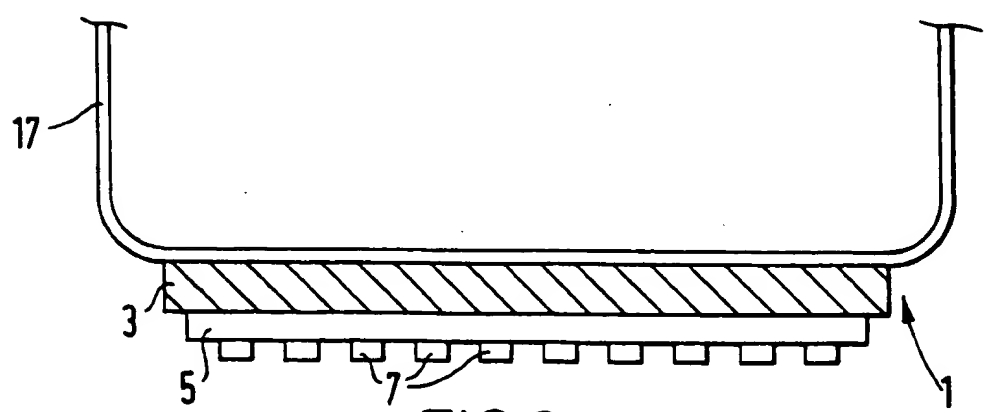

FIG.3

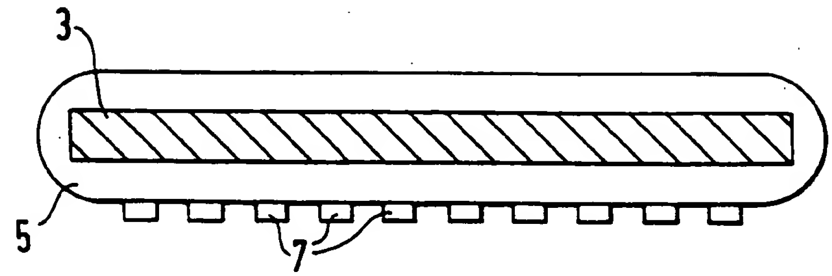

FIG. 4

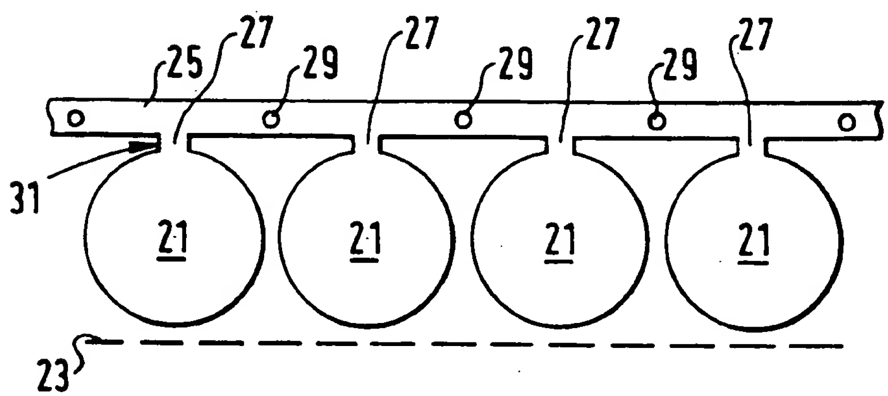

FIG.5

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 98/02347

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H05B3/82 H05B3/26 H05B3/30

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H05B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 574 310 A (SEB SA) 15 December 1993 see claims 1,3	1,3
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☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
3 November 1998	09/11/1998

Name and mailing address of the ISA	Authorized officer
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Information on patent family members

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